Case Studies of Airborne Radiometer Signals over the Ocean

Richard D. West and Simon H. Yueh

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109-8099
Phone: 818-354-6025, Fax: 818-393-5184, Email: Richard.D.West@jpl.nasa.gov

Abstract – This paper presents some case studies of multi-frequency multi-polarization brightness temperatures obtained in a variety of surface and atmospheric conditions. All of the channels showed the characteristic sinusoidal modulation with azimuth caused by wind stress on the ocean surface. The lowest frequency channel (10 GHz) seemed to show more modulation than other frequencies, especially in the U channel. The U channel was the least sensitive to the atmospheric conditions.

I. INTRODUCTION

Ocean winds are important to weather prediction and climate studies. They drive ocean currents which distribute heat around the globe and help to determine regional weather patterns. Radiometers can be used to measure the surface winds over the oceans because the winds affect the emissivity of the surface [1]. The emissivity of the ocean surface is determined by physical factors such as the dielectric contrast, and the surface roughness. Small scale roughness generated by surface winds modifies the emissivity by scattering the emitted radiation over a range of directions.

The radiation emitted by the ocean surface is also affected by absorption and radiation in the atmosphere before it reaches the satellite radiometer. In the microwave frequency range, the most important factors are water vapor and liquid water in clouds. Thus, the atmosphere represents a source of bias and noise in the surface emission signal. In this paper, we will examine some multi-frequency aircraft radiometer data obtained by the Jet Propulsion Laboratory (JPL) WindRad experiment, and by two Naval Research Laboratory (NRL) radiometers operated on the same aircraft.

II. DATA

The WindRad radiometers operate at 19 and 37 GHz, while the NRL radiometers operate at 10 and 22 GHz. [2], [3]. Data from September, 1995 is presented in this paper. The wind speed, wind direction, and sea surface temperature were obtained from National Data Buoy Center (NDBC) buoys, ship measurements, and coincident radiosonde measurements. Brightness temperatures were measured at vertical polarization, horizontal polarization, +45° linear polarization, and −45° linear polarization. The stokes parameter Q is $T_v - T_h$, and the stokes parameter U is $T_{+45} - T_{-45}$. The stokes parameter V can be measured using circular polarization, but it was not always obtained and is not shown in the figures. The 22 GHz data only includes T_v and T_h polarizations. All of the data shown in this paper were measured at an incidence angle of 45 deg, and have been corrected for aircraft attitude variation.

This work was performed under contract with the National Aeronautics and Space Administration at the Jet Propulsion Laboratory, California Institute of Technology

III. CASE STUDIES

The figures present three pairs of plots with the 10 and 22 GHz data on the first plot, and the 19 and 37 GHz data on the second plot in a pair. Each plot contains four graphs of the stokes parameters T_v, T_h, Q, and U. The mean value of the brightness temperatures for each frequency are subtracted to allow easier comparison of the signal variations. All of the plots show sinusoidal variation with azimuth because of wind modulation of the surface. The U channel provides the cleanest signal because it is the least sensitive to the atmosphere.

Figs. 1 and 2 show data for low wind conditions on Sep 22, 1995. All four frequencies show erratic signals in the T_v, T_h, and Q channels. The U channel is noisy with a signal strength less than 1 K peak to peak. No reliable distinction between frequencies can be made. The average levels subtracted out for T_v and T_h in the following order (T_v(10 GHz), T_h(10 GHz), T_v(19 GHz), T_h(19 GHz), T_v(22 GHz), T_h(22 GHz), T_v(37 GHz), T_h(37 GHz), are (K): 137, 92, 176, 125, 209, 167, 192, and 142. The U channel has a mean very close to zero in all cases.

Figs. 3 and 4 show data for moderate wind conditions on Sep 23, 1995. The azimuthal wind modulation is much more clear in this case. In the NRL data, the 22 GHz data is noisy with a peak to peak modulation of about 1.5 K in T_v and T_h. This matches the modulation apparent in the 19 and 37 GHz data. The 10 GHz data appears to have a slightly larger modulation of 2 K in T_v and T_h. In the U channel, we see the largest difference with the 10 GHz temperatures varying 4 K peak to peak, while the 19 and 37 GHz temperatures vary about 2 K peak to peak. The average levels subtracted out are: 135, 91, 175, 126, 203, 160, 187, and 138.

Figs. 5 and 6 show data for high wind conditions on Sep 21, 1995. This data was obtained over Hurricane Juliette 230 km from the eye of the storm. Despite the cloudy

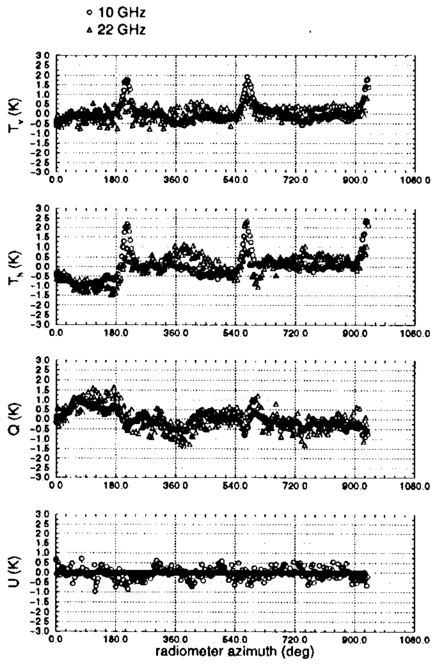

Figure 1. NRL data for 10 and 22 GHz at an incidence angle of 45° on Sep 22, 1995. The buoy groundtruth is: wind speed = 4.4 m/s, wind direction = 272 deg. (from), sea surface temperature = 19.1°C. Sky conditions: thin low clouds, Aircraft altitude: 8530 meters.

conditions, a definite wind modulation is apparent in all of the radiometer channels. The T_v channel shows about 2 K of peak to peak modulation at 22 GHz, and a slightly larger modulation (2.5 - 3.0 K) at the other frequencies. The 22 GHz channels may be more affected by clouds than the other frequencies because they lie very close to a water vapor absorption line. The T_h channel may have a slightly larger signal in all cases. Again, in the U channel, we see the largest difference. The 10 GHz temperatures vary 5 K peak to peak, while the 19 and 37 GHz temperatures vary about 3 K peak to peak. The average levels subtracted out are: 150, 109, 208, 173, 255, 241, 216, and 183.

IV. SUMMARY

The case studes examined in this paper indicate that microwave brightness temperatures over the ocean can reveal useful information about surface winds in a variety of weather conditions. The 22 GHz data is the most noisy, probably because it is more sensitive to absorption by water vapor. The 10 GHz data shows more modulation in the U channel than the higher frequency data which may be due to differences in the surface roughness spectrum at different length scales.

V. ACKNOWLEDGMENTS

We would like to thank the Naval Research Laboratory for supplying their 10 and 22 GHz data from the flights discussed in this paper.

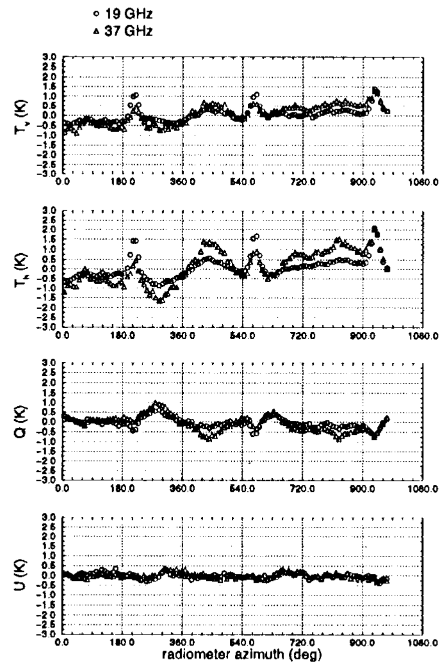

Figure 2. WindRad data for 19 and 37 GHz. Other parameters match preceeding figure.

REFERENCES

[1] F. J. Wentz, "Measurement of oceanic wind vector using satellite microwave radiometers," IEEE Trans. on GeoScience and Remote Sensing, vol. 30, no. 5, pp. 960-972, September 1992.

[2] S. H. Yueh, William J. Wilson, Fuk K. Li, Son V. Nghiem, and William B. Ricketts, "Polarimetric Measurements of Sea Surface Brightness Temperatures Using an Aircraft K-Band Radiometer," IEEE Trans. on GeoScience and Remote Sensing, vol 33, no. 1, pp. 85-92, January 1995.

[3] S. H. Yueh, William J. Wilson, Fuk K. Li, Son V. Nghiem, and William B. Ricketts, "Polarimetric Brightness Temperatures of Sea Surfaces Measured with Aircraft K- and Ka-Band Radiometers," IEEE Trans. on GeoScience and Remote Sensing, vol 35, no. 5, pp. 1177-1187, January 1997.

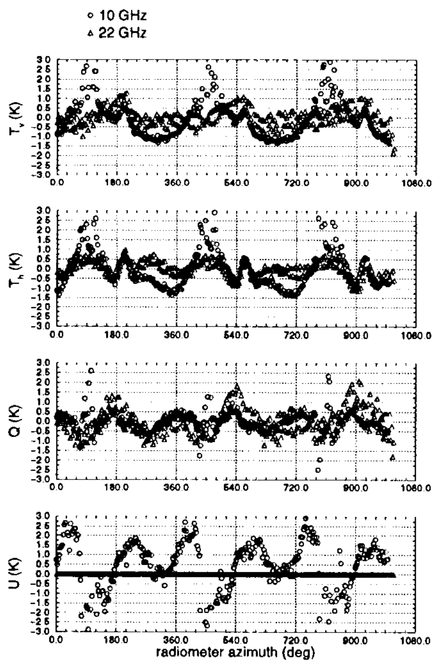

Figure 3. NRL data for 10 and 22 GHz at an incidence angle of 45° on Sep 23, 1995. The groundtruth (from FLIP ship) is: wind speed = 7.2 m/s, wind direction = 200 deg. (from), sea surface temperature = 13.9°C. Sky conditions: mostly clear, thin low clouds. Aircraft altitude: 9140 meters.

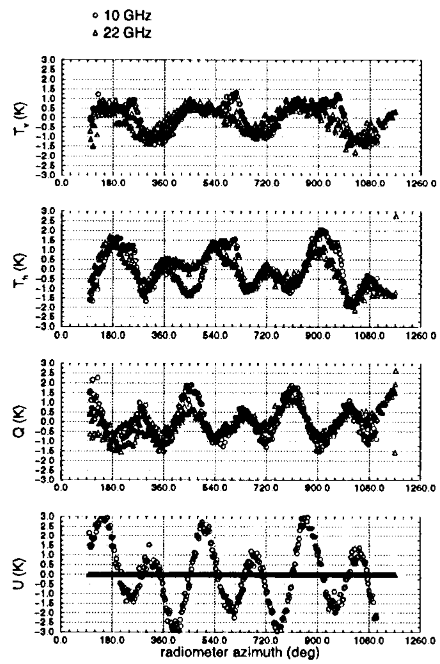

Figure 5. NRL data for 10 and 22 GHz at an incidence angle of 45° on Sep 21, 1995. The groundtruth (from radiosonde) is: wind speed = 14.4 m/s, wind direction = 198 deg. (from), sea surface temperature = 20°C. Sky conditions: cloudy (Hurricane Juliette, 230 km from eye) Aircraft altitude: 8230 meters.

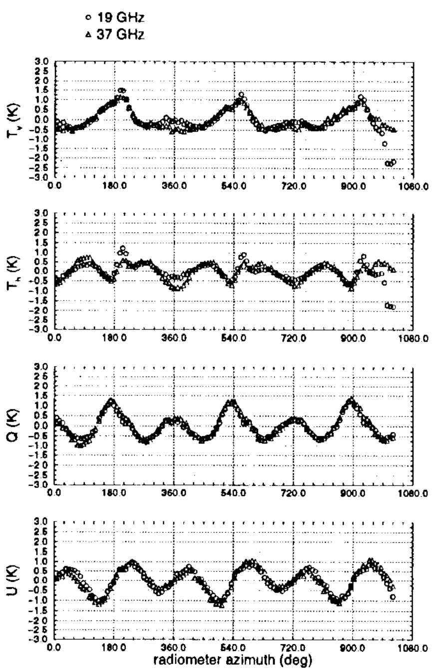

Figure 4. WindRad data for 19 and 37 GHz. Other parameters match preceeding figure.

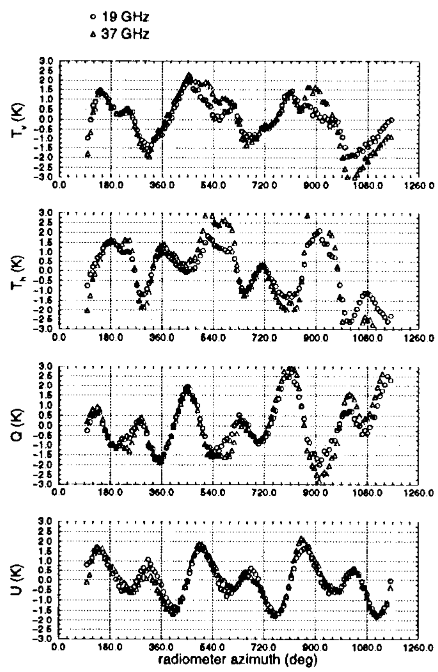

Figure 6. WindRad data for 19 and 37 GHz. Other parameters match preceeding figure.